

Atmospheric aerosol pollution caused by world food cultivation

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Motivation:



- Particulate matter is a concern for public health.
- To assist policy makers, it is important to connect the chemical composition and severity of particulate pollution to its sources.
- Here we show how agricultural practices, livestock production, and the use of nitrogen fertilizers impact near-surface air quality.

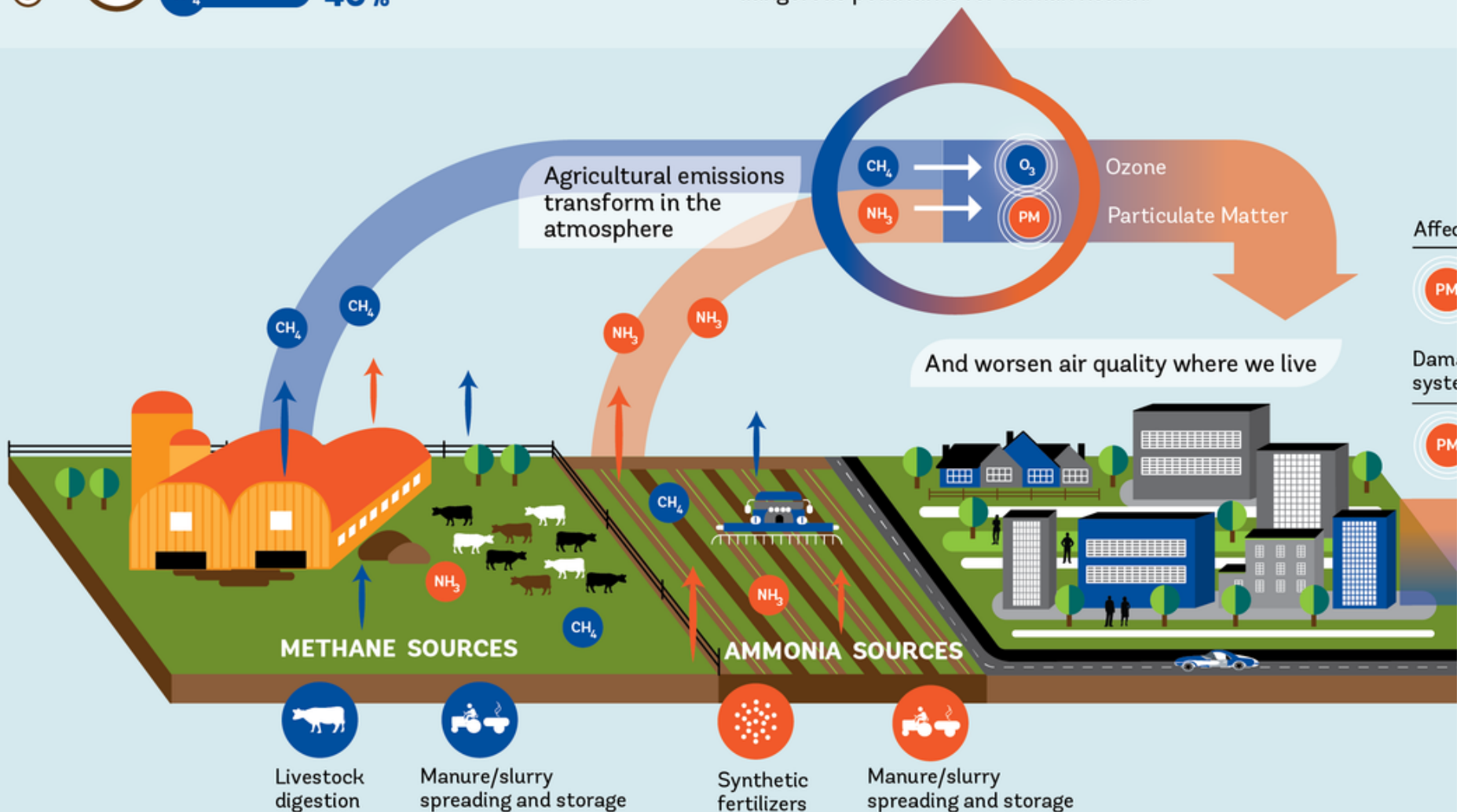
AGRICULTURAL EMISSIONS

Agriculture is the main source of ammonia (NH_3) and methane (CH_4) in the EU.



AIR QUALITY & HEALTH

Ammonia (NH_3) and methane (CH_4) are major contributors to Particulate Matter (PM) and ozone (O_3) - the most dangerous pollutants for human health.

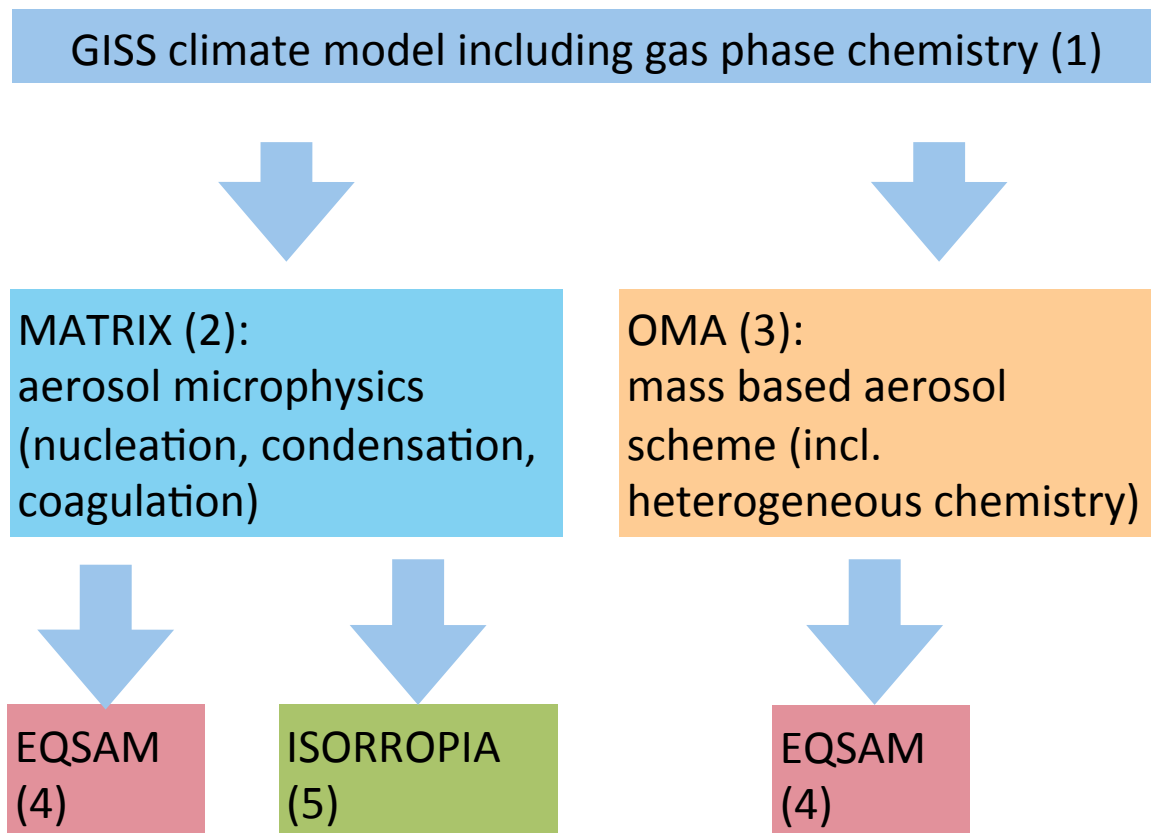


Motivation:



- First step: A model that can simulate the reactive atmospheric nitrogen cycle

Model Systems including atmospheric gas and aerosol phase chemistry:



References:

- (1) Schmidt et al 2014 J Adv Model Earth Syst.
- (2) Bauer et al 2008, ACP
- (3) Bauer et al 2007 ACP
- (4) Metzger et al 2006 ACP
- (5) Fountoukis 2009 ACP

How well do we simulate Secondary Inorganic Aerosols?

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1 **Evaluating Secondary Inorganic Aerosols in 3-Dimensions**

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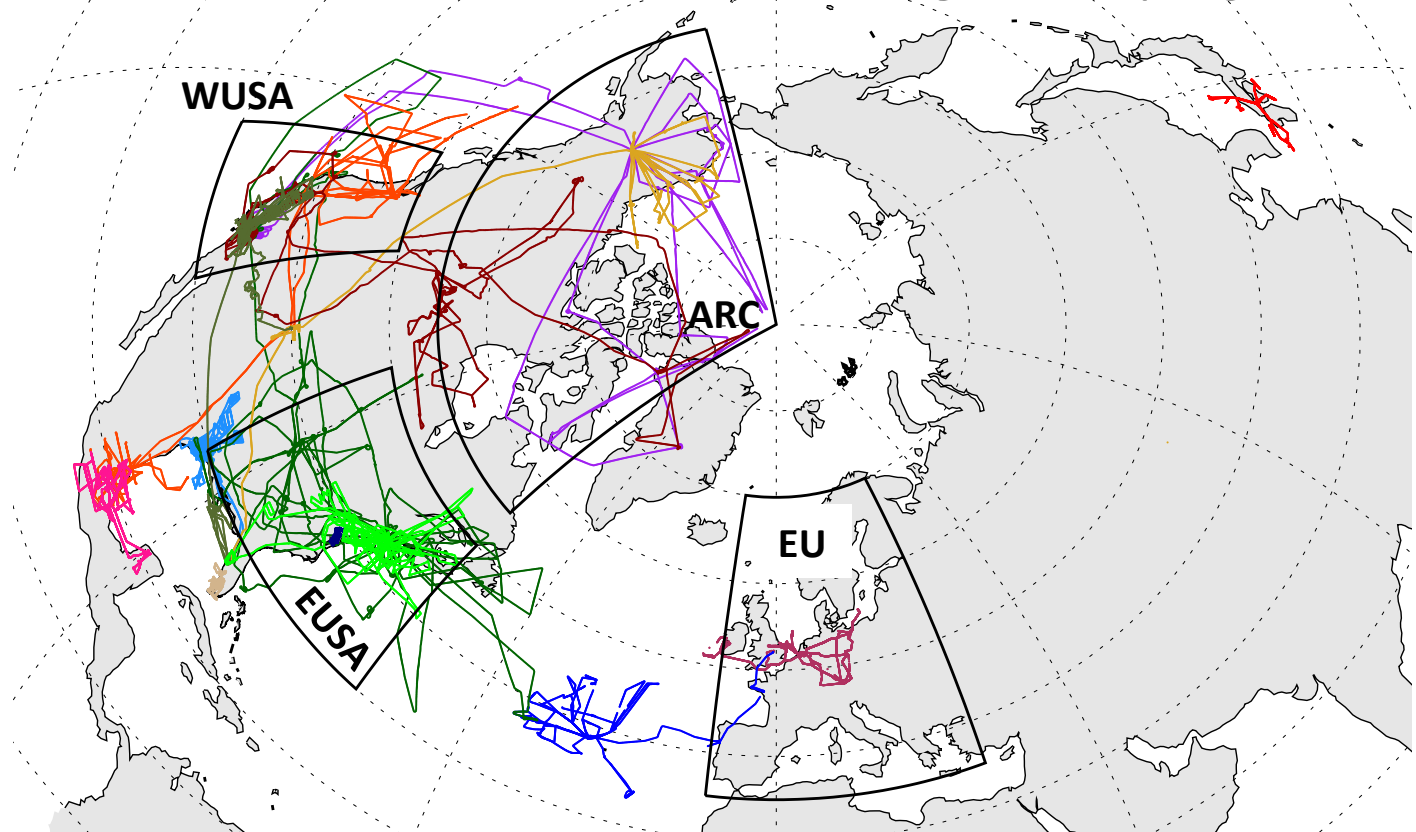
Evaluation

Time: 2000-2010

Location: NH

Data: surface networks (EMEP, IMPROVE) and flight campaigns*

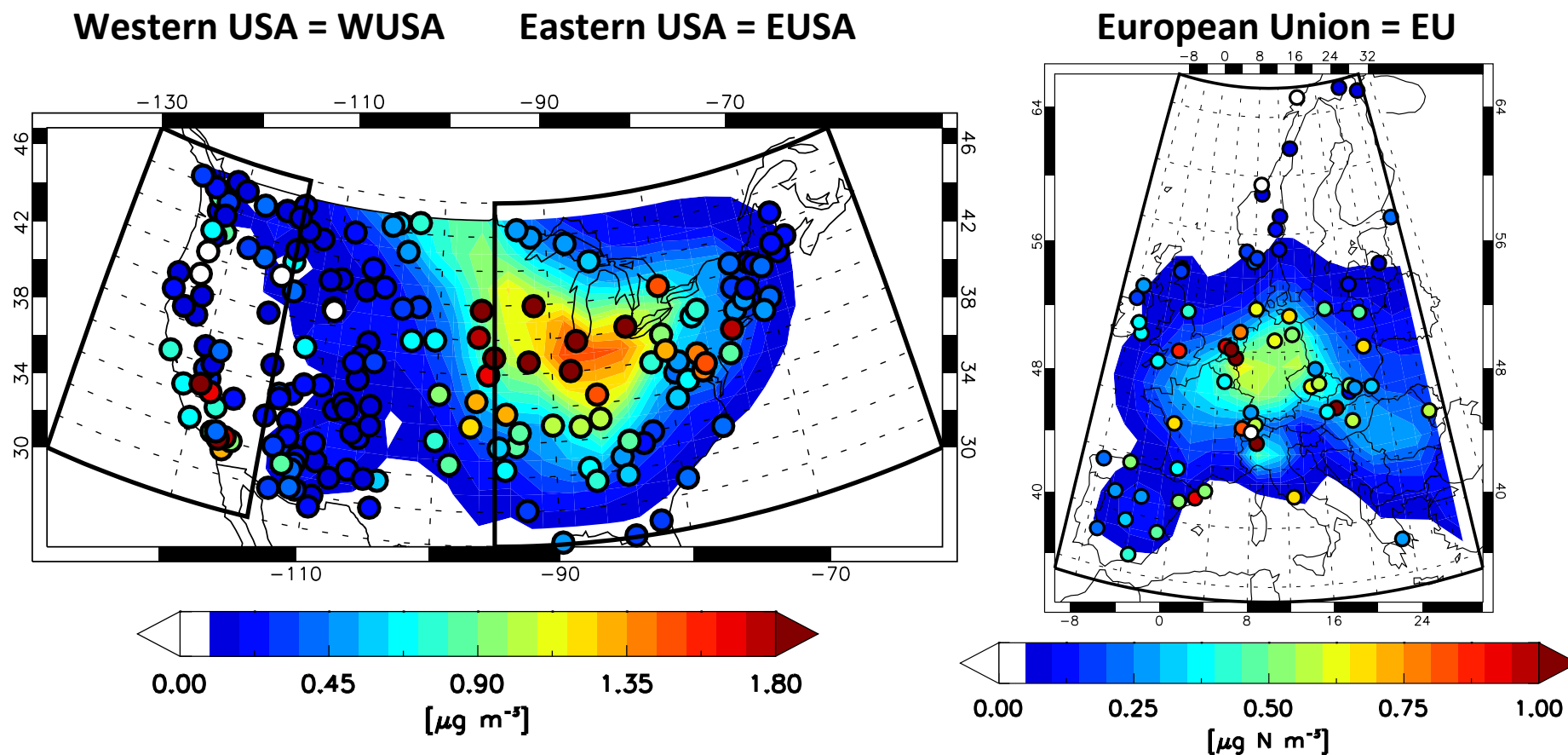
EUCAARI
ARCTAS spring
TEXAQs
ITOP-UK
INTEX-A
INTEX-B
ARCPAC
ARCTAS sumeers
DISCOVER-MD
CALNEX
CRISTAL-FACE
ACE-ASIA
MILAGRO-MIRAGE
NEAQs



*re-grid and average according to the model's corresponding grid box height

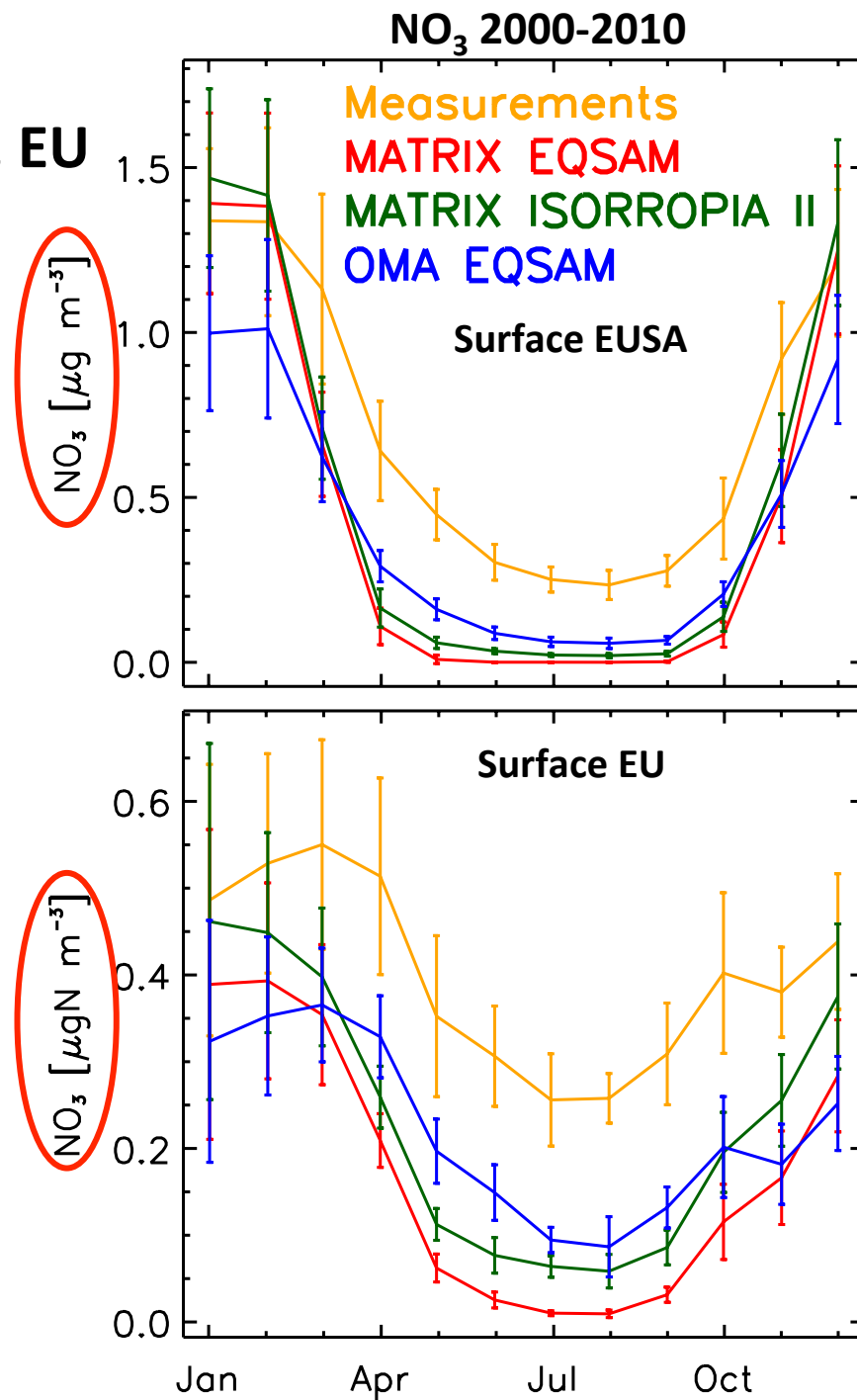
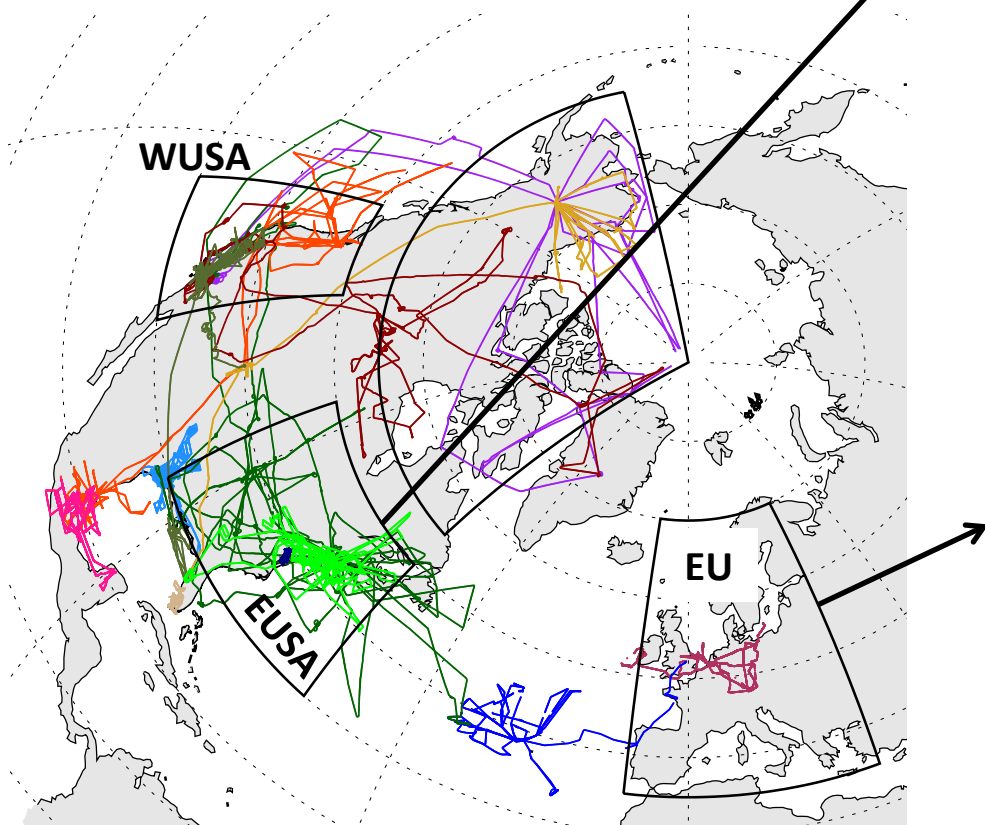
Spatial patterns → regional perspective

Surface NO₃ 2000-2010, (MATRIX EQSAM, OBS)

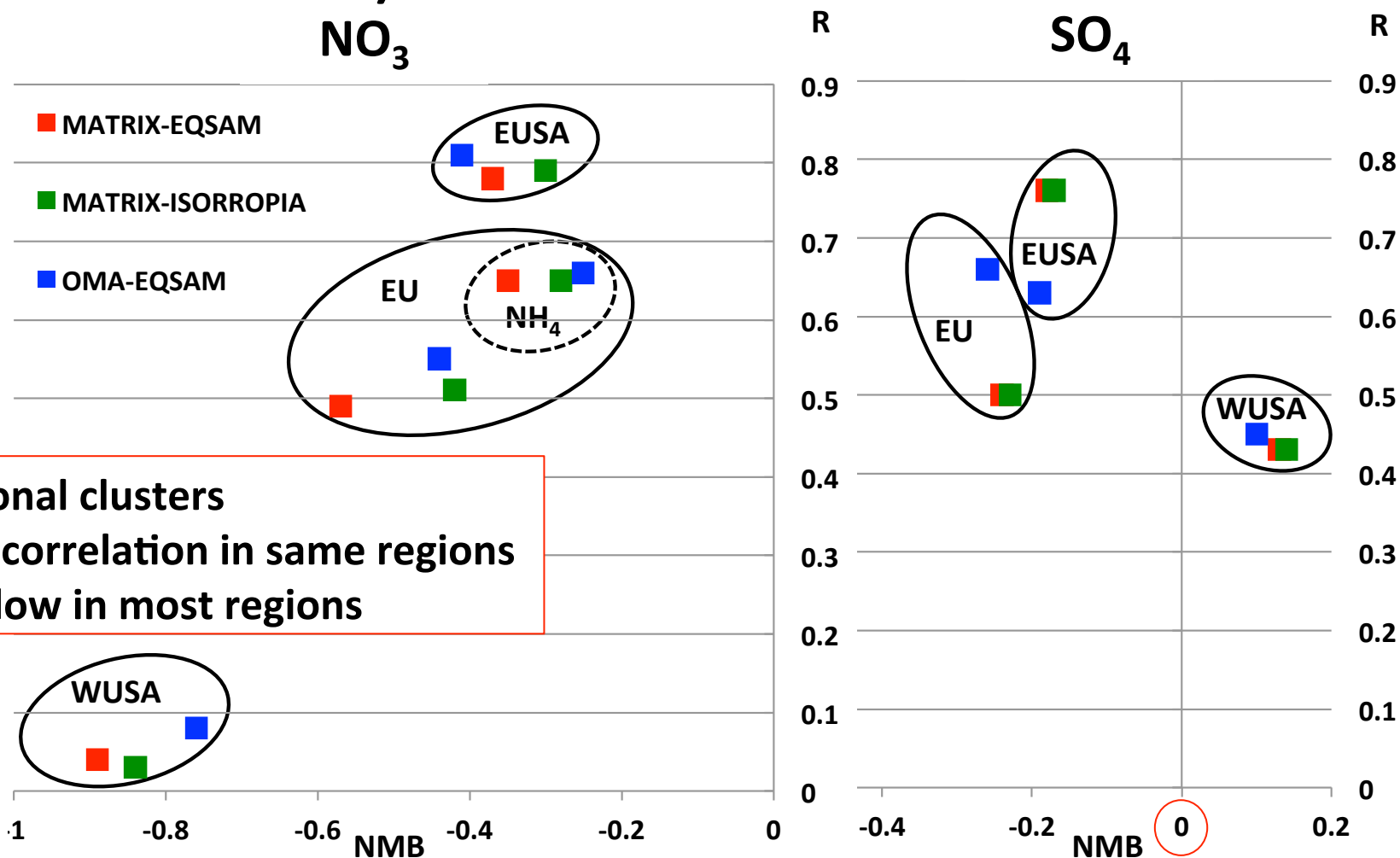


NO₃ seasonality is captured in EUSA, EU

Underestimation, especially in summer



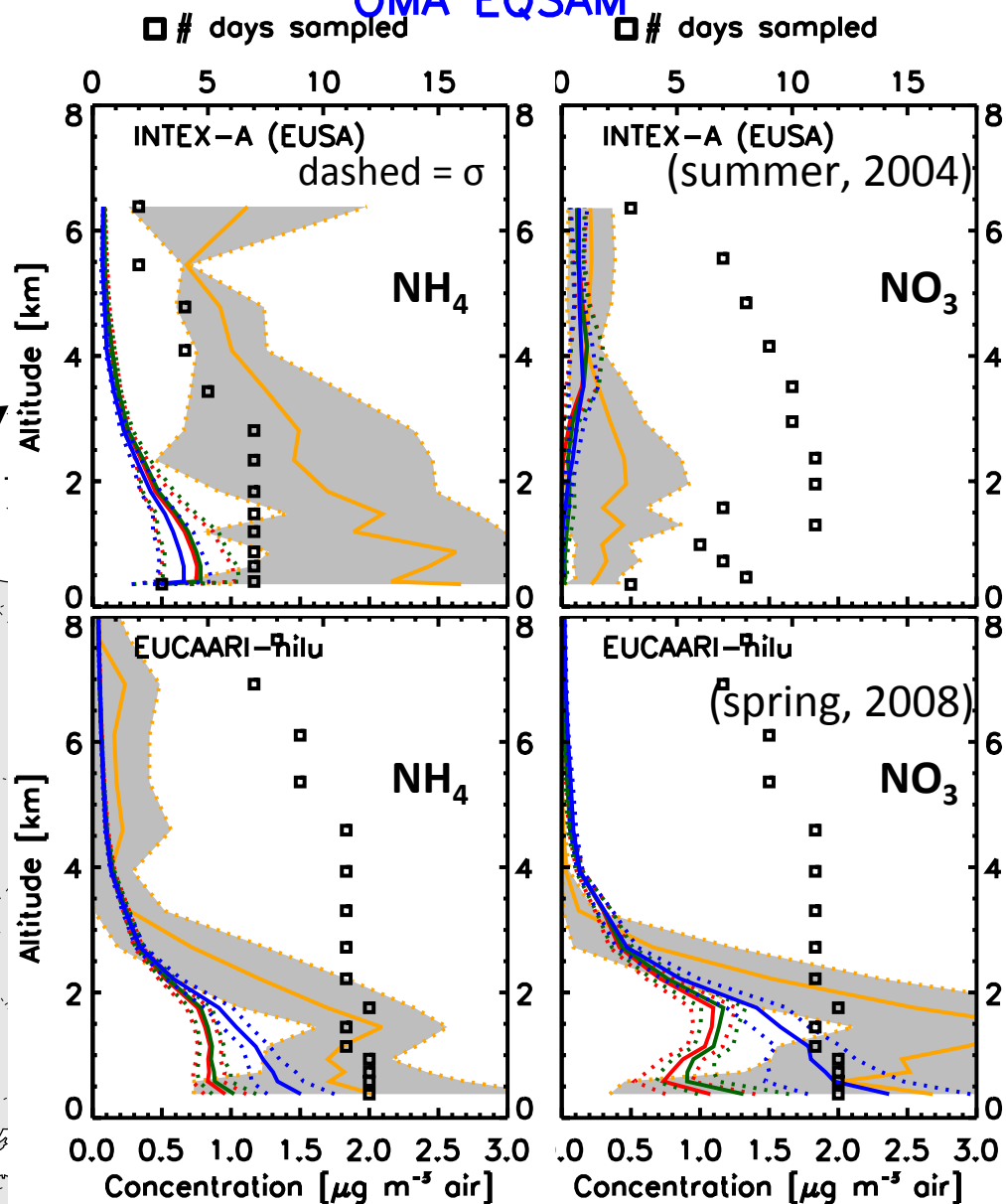
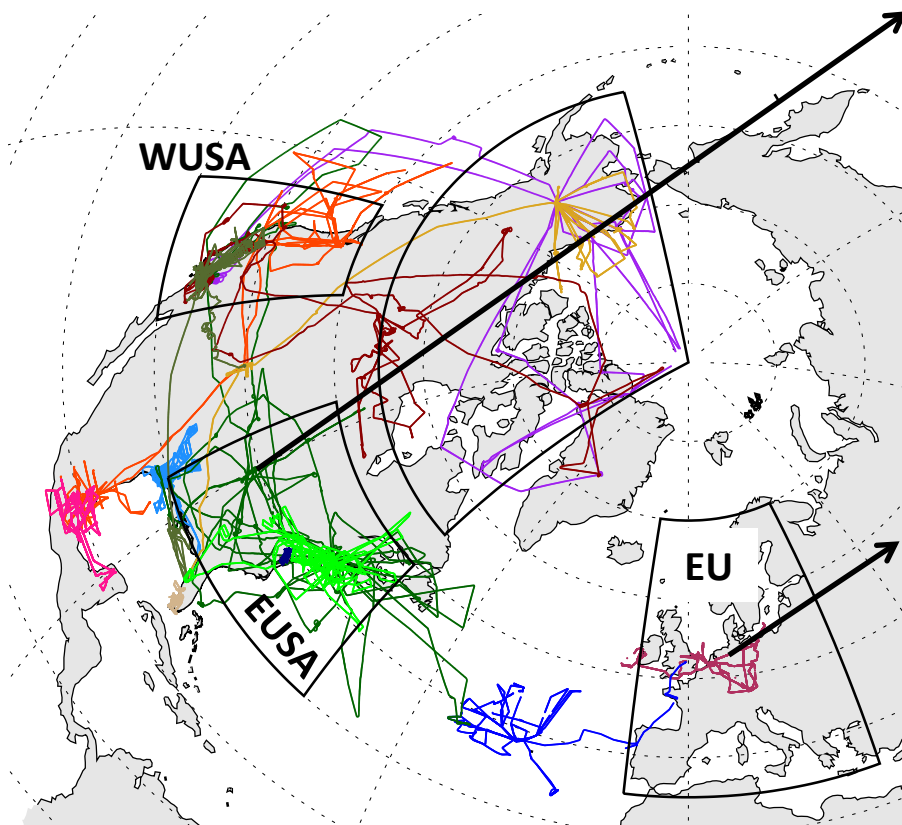
Good agreement in EUSA, EU (surface 2000-2010)



NH₄ and NO₃ behavior

In polluted regions
underestimation is consistent
with surface behavior

Measurements
MATRIX EQSAM
MATRIX ISORROPIA II
OMA EQSAM



Summary of evaluation study:

- Secondary inorganic aerosol mass, ammonium, nitrate and sulfate are all underestimated in all model configurations.
- Biases are more defined by region, than by model configuration.
- Correlation coefficients are high for all species.
- For more details, and ideas how to improve models, please discuss with Keren and see her poster.

Relevance for agricultural emission study:

- With the previous study we identified MATRIX-ISORROPIA to give the best SIA simulation, thus we will use that version for this study.
- We actually used all versions for this study and got similar results.
- Overall surface (air pollution) nitrate concentrations are underestimated, thus the following results will be biased low.

Atmospheric aerosol pollution caused by world food cultivation

Short - Lived Species

Aerosol and Ozone precursor emission:

- Animal manure and synthetic fertilizers leads to emission of ammonia (NH_3).
- Agricultural practices including waste burning, produce CO , NO_x , VOC's , SO_2 , NO_x , BC and OC .

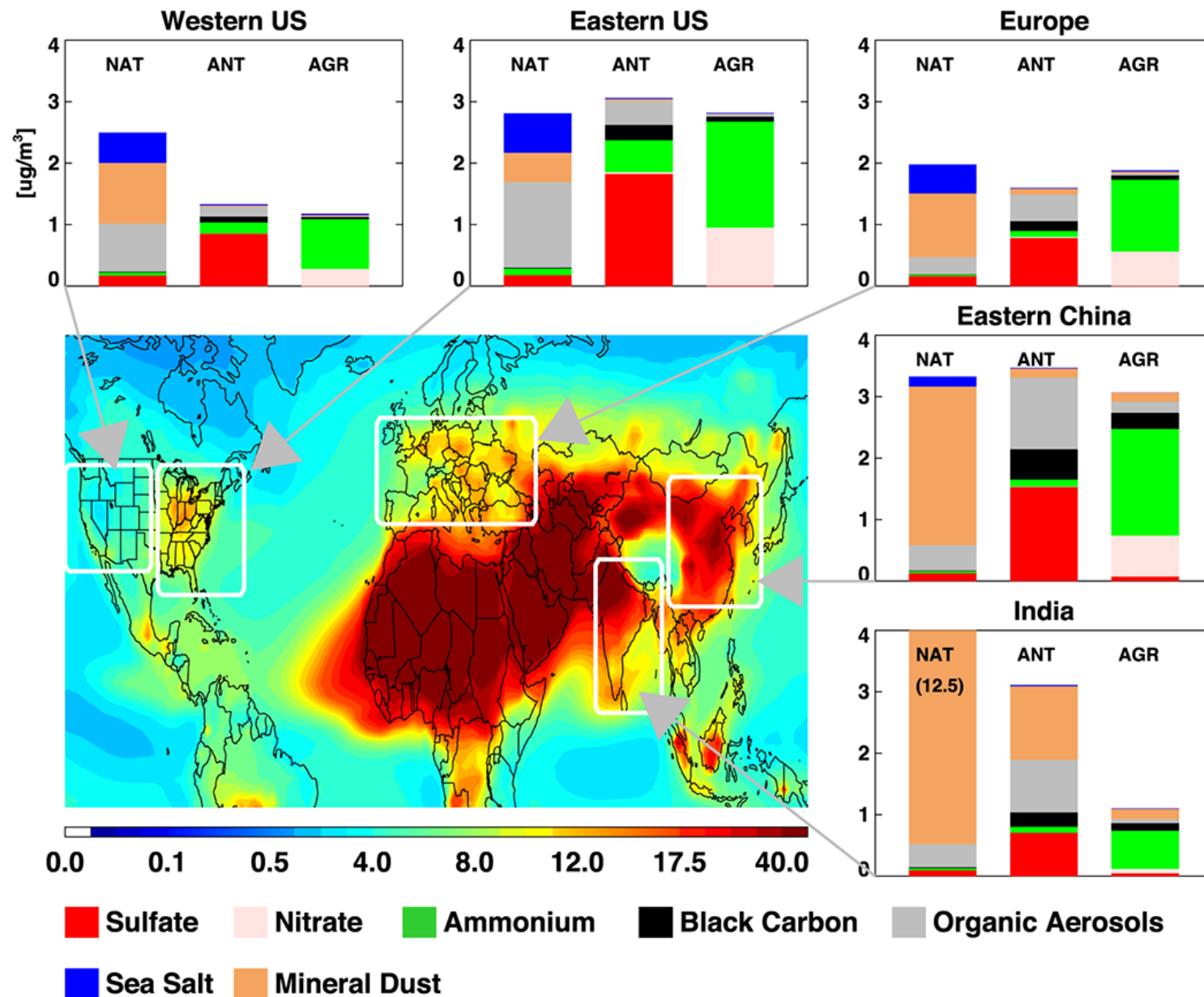
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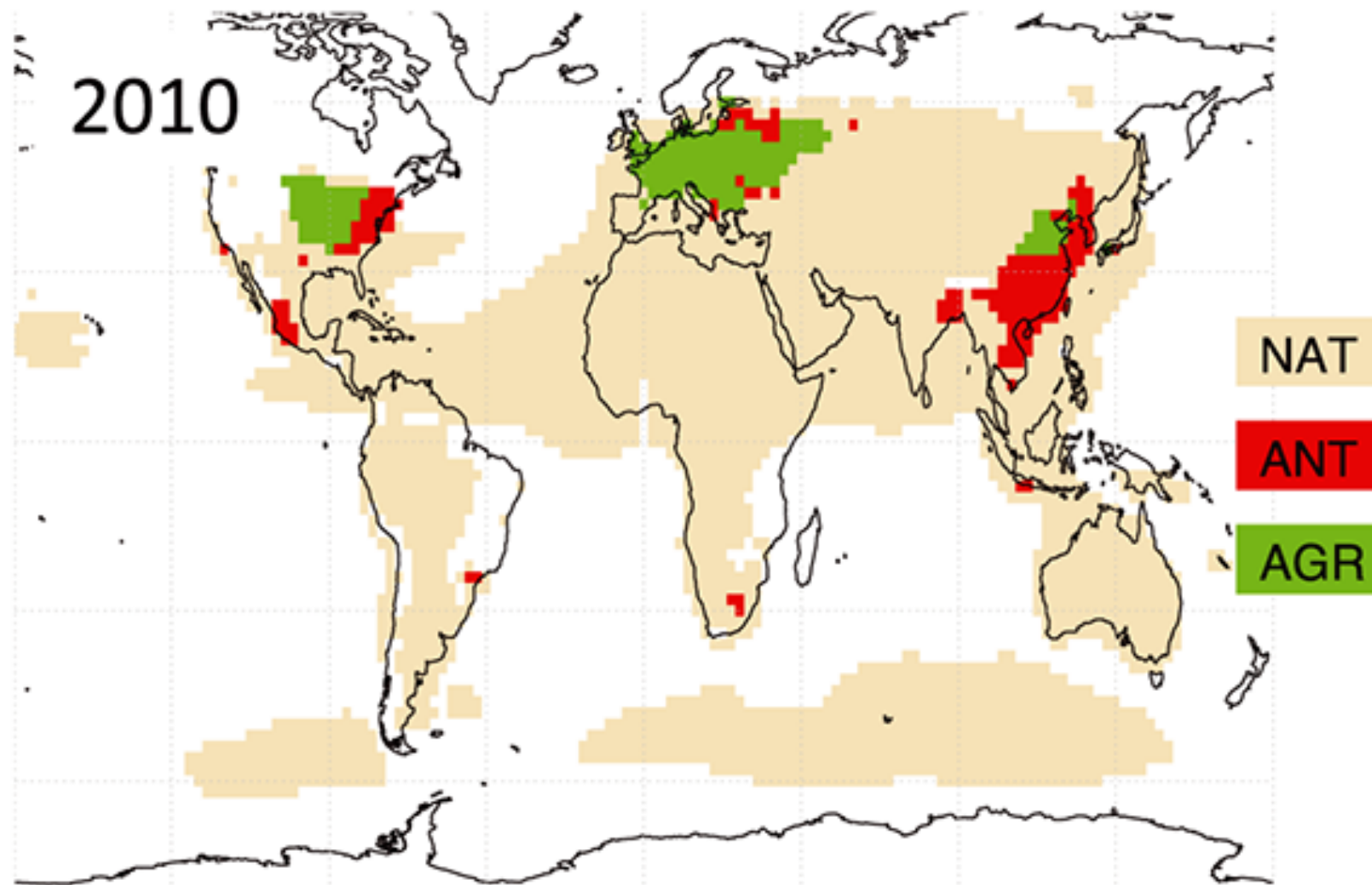
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Annual mean total PM_{2.5} concentrations in $\mu\text{g}/\text{m}^3$.
 (NAT = natural, ANT = anthropogenic without agricultural, AGR = agricultural sources)



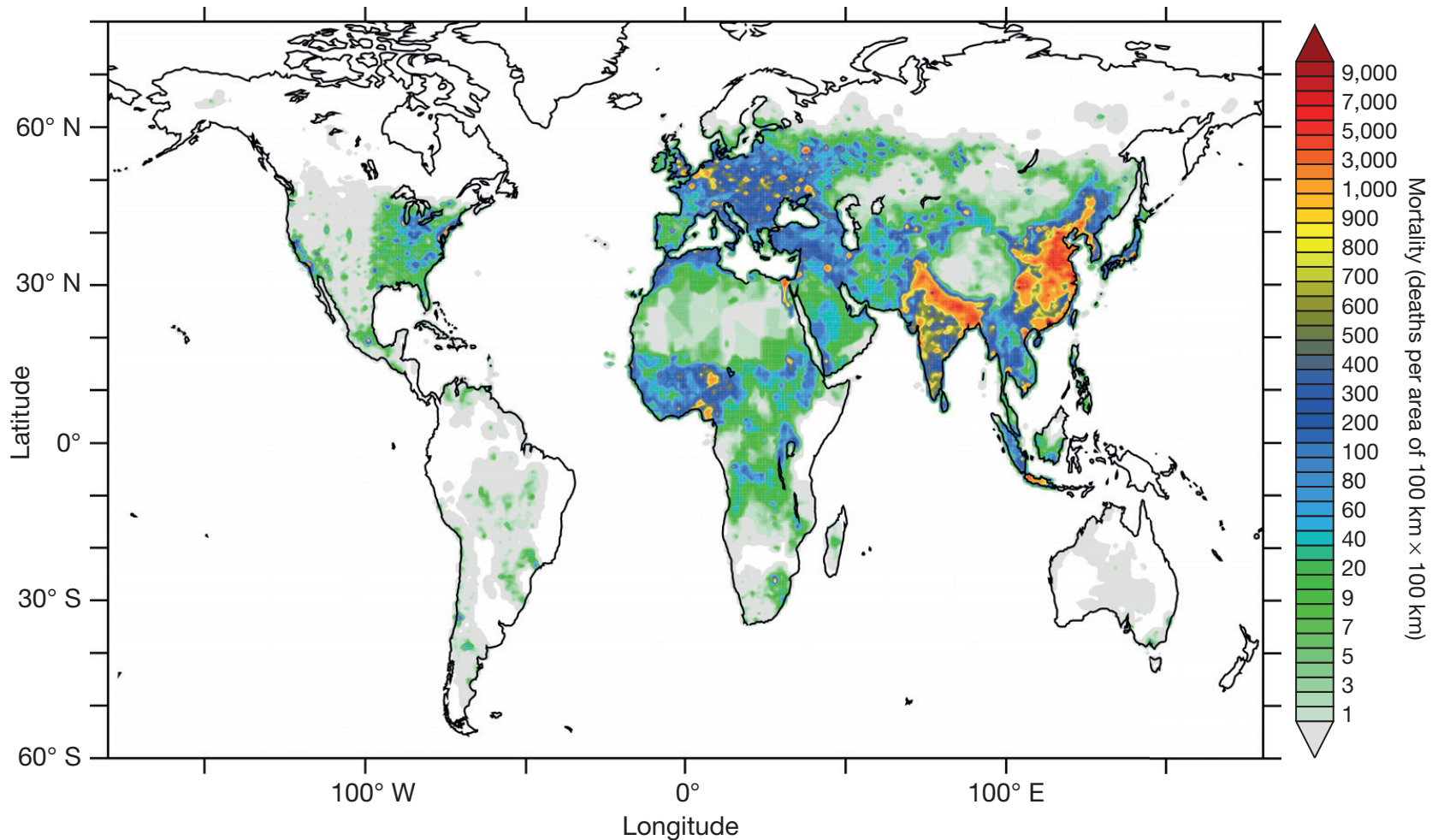
Dominant contributor to PM_{2.5} concentrations with respect to natural, anthropogenic (without agriculture), and agricultural sources. Areas with PM_{2.5} concentrations below 3 µg/m³ are white



Mortality linked to outdoor air pollution in 2010.

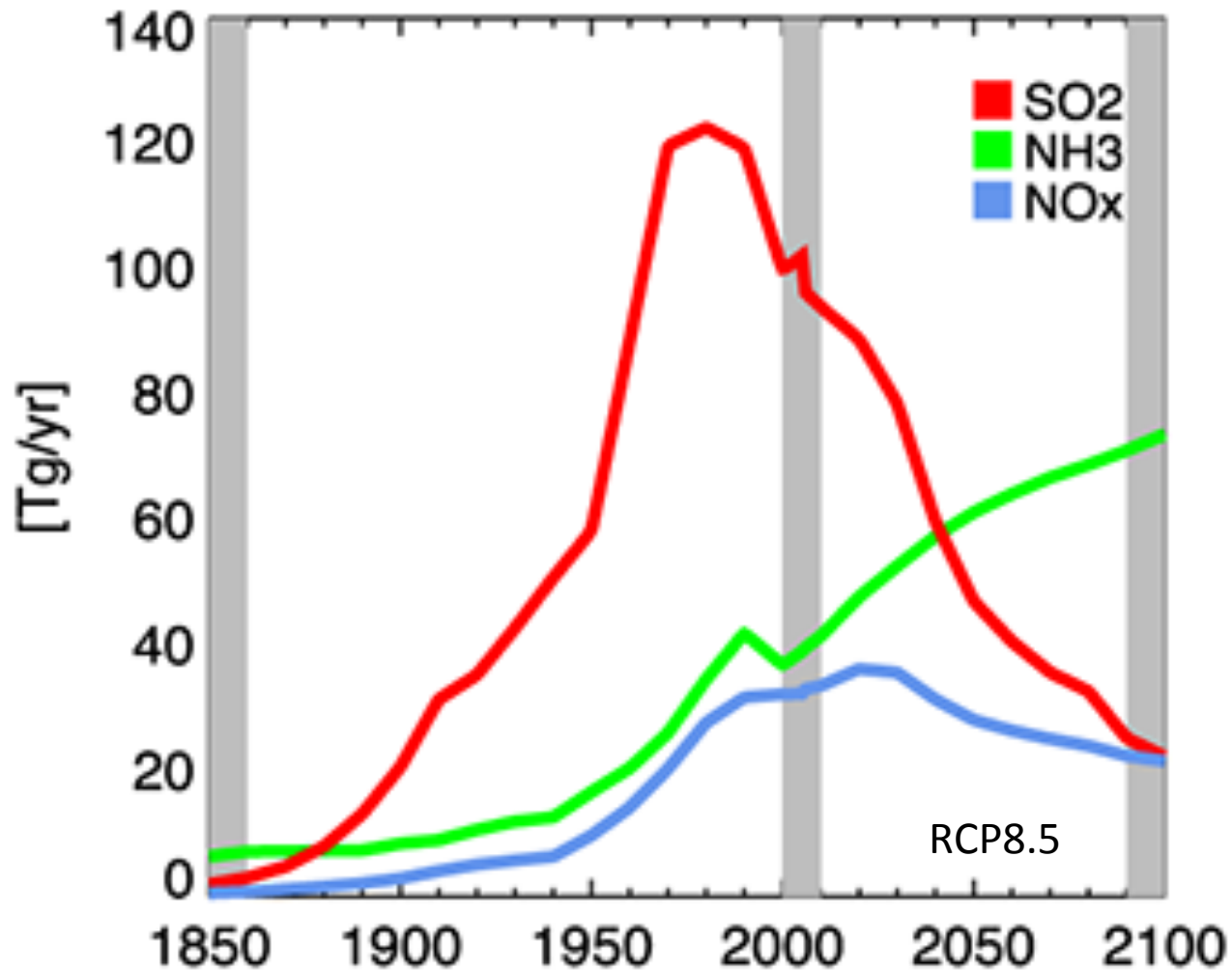
Lelieveld, Nature 2015.

Units of mortality, death per area 100 x 100 km

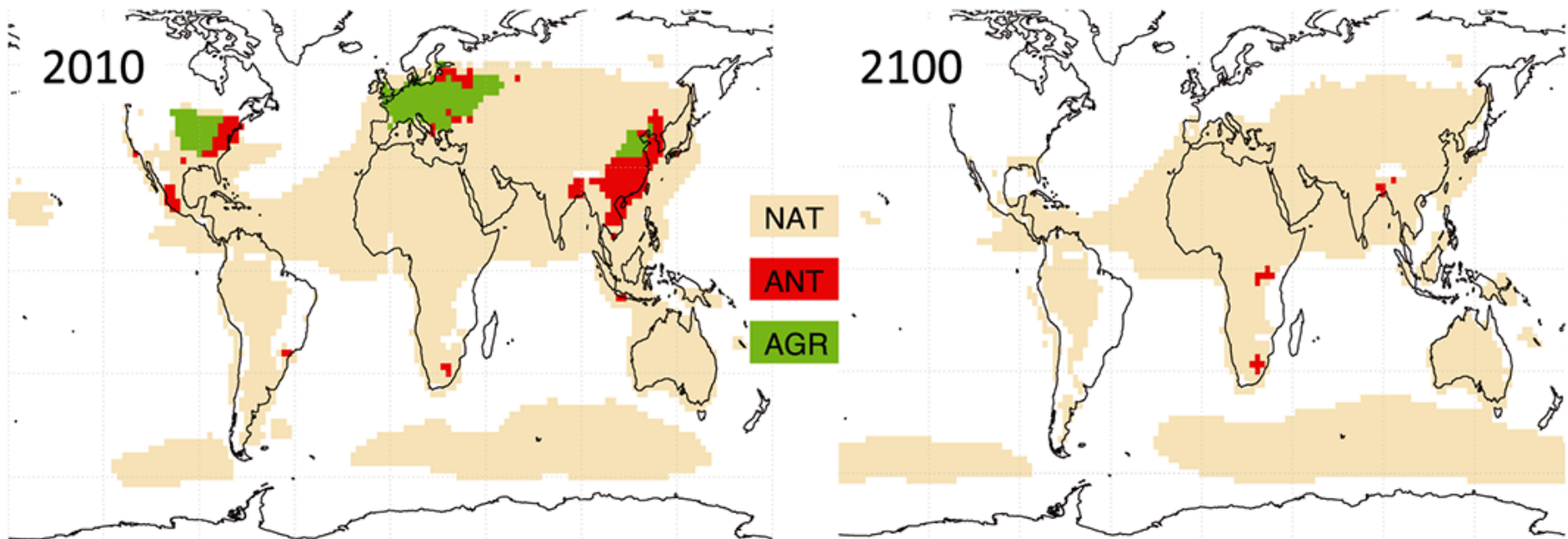


Air pollution, mostly by PM_{2.5}, leads to 3.3 (95% confidence interval 1.61–4.81) million premature deaths per year worldwide.

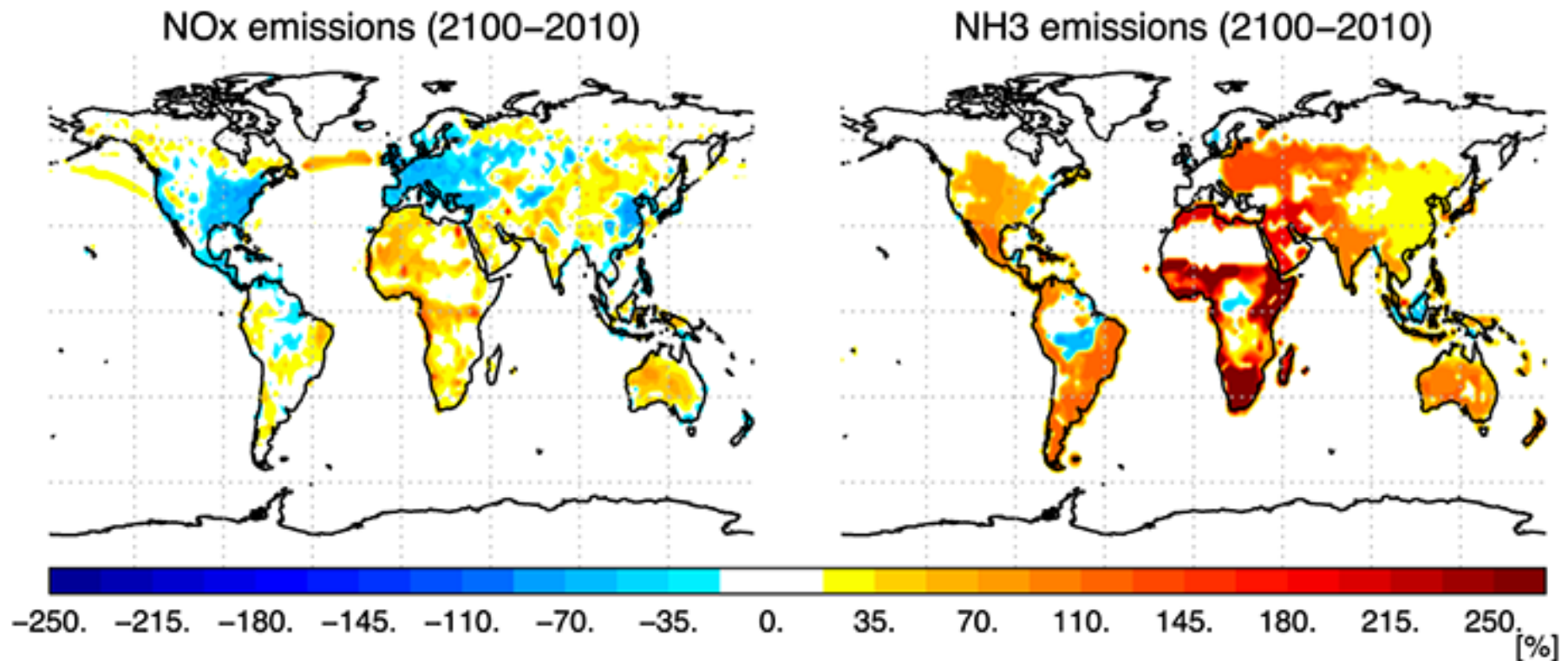
How will the future look like?



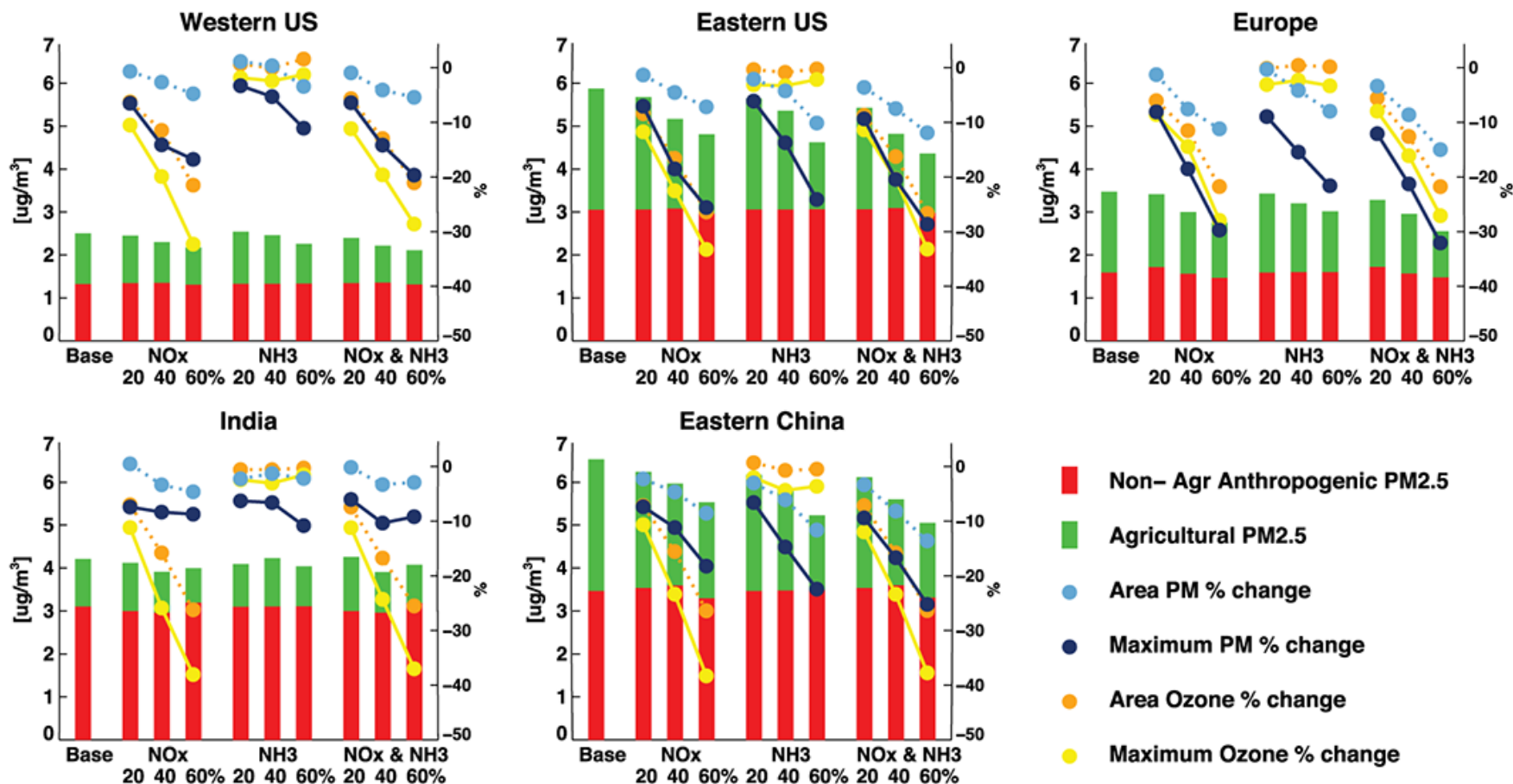
Dominant contributor to PM_{2.5} concentrations with respect to natural, anthropogenic (without agriculture), and agricultural sources.



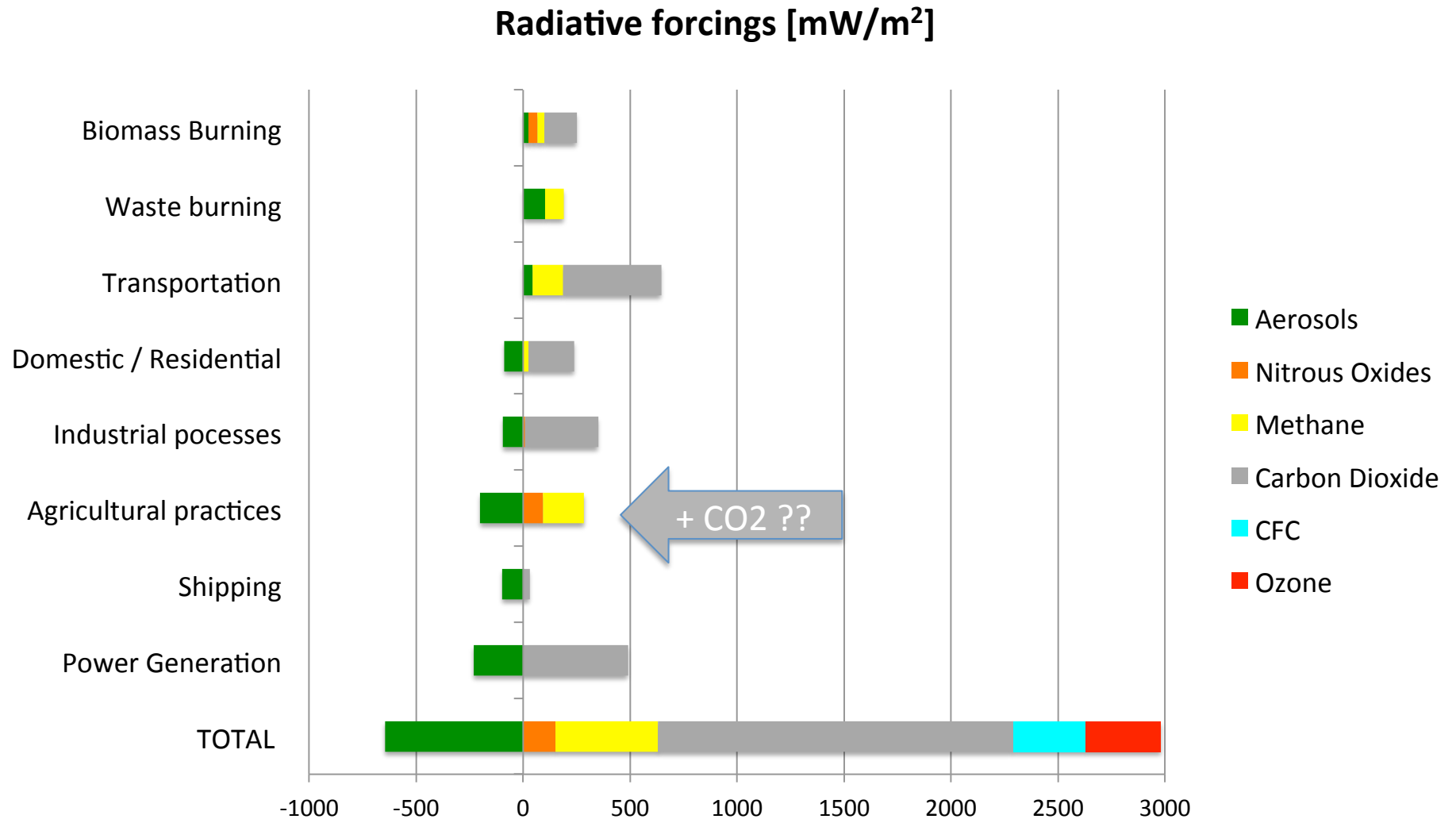
Percentage differences in emission fluxes (%) between 2010 and 2100 for (middle) NO_x and (right) NH_3 .



Regional means of PM_{2.5} from the agricultural sector (green), and nonagricultural anthropogenic sector (red), for the base run and the experiments with reductions in anthropogenic NO_x emissions, agricultural NH₃ emissions, and a combination of both by 20%, 40%, and 60%, respectively. Percentage changes for regional means (dashed lines) and maximum reductions per region (solid lines) are shown for PM_{2.5} (blues) and surface ozone (yellow, orange) concentrations.



Aerosol forcings in relation to GHG forcings



Bauer and Menon, JGR, 2012

Long - Lived Species

GHG emissions form Agriculture:

- Soil management, use of fertilizers, leads to emission of nitrous oxide (N₂O).
- Livestock, especially cattle, and rice production produces methane (CH₄)
- Manure from livestock and agricultural waste burning produce CH₄, N₂O and CO₂ emissions.

GHG from Agriculture:

CO₂ (21%–25% of total CO₂ emissions) from fossil fuels used on farms, but mainly from deforestation and shifting patterns of cultivation;

CH₄ (55%–60% of total CH₄ emissions) from rice paddies, land use change, biomass burning, enteric fermentation, animal wastes;

N₂O (65%–80% of total N₂O emissions) mainly from nitrogenous fertilizers on cultivated soils and animal wastes (OECD, 1998)

Conclusion

- **Today:** Agricultural emissions contribute to PM pollution, and dominate over all other anthropogenic sources in wide regions over the US, Europe and Asia.
- **Future:** More Nitrate aerosol in the atmosphere but less at the surface. Thus less of an issue for air quality. Aerosol forcing by the end of the century will be dominated by aerosols from agriculture.
- **Future:** Agriculture contributes currently to over 20% of global anthropogenic greenhouse gas emissions. Increasing world population will increase the importance of GHG released by agriculture.

Anthropogenic enhanced agricultural air pollution

Agricultural Air Pollution is still a 'developed' country problem: Currently, Air Pollution in the Netherlands reduced life expectancy by 1 year!

The choice of food production practices can be a problem or part of a solution in addressing climate change.

References:

Bauer et al, GRL, 2016, Significant atmospheric aerosol pollution caused by world food cultivation

Mezuman et al, ACDP, 2016, Evaluating Secondary Inorganic Aerosols in 3-Dimensions

Lelieveld et al, Nature, 2016, The contribution of outdoor air pollution sources to premature mortality on a global scale

Bauer and Menon, JGR, 2012, Aerosol direct, indirect, semi-direct, and surface albedo effects from sector contributions based on the IPCC AR5 emissions for preindustrial and present-day conditions



Veggies for
Dinner?

Why do I
work with
vegans?

THANK YOU!!!